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LMSC D764514

SATELLITE SERVICES SYSTEM ANALYSIS STUDY

NASA-CR-16105

FINAL REPORT PART II VOLUME 1

EXECUTIVE SUMMARY

CONTRACT NAS 9-16121

DRL ITEM NO. MA-834T
LINE NO. 4

22 JULY 1981

NASA JOHNSON SPACE CENTER

LOCKHEED MISSILES & SPACE COMPANY, INC. SUNNYVALE, CALIFORNIA

LMSC-D764514

SATELLITE SERVICES SYSTEM ANALYSIS STUDY

EXECUTIVE SUMMARY
PART II

PRESENTED BY
LOCKHEED MISSILES & SPACE COMPANY, INC.
SUNNYVALE, CALIFORNIA

TO

NASA JOHNSON SPACE CENTER
HOUSTON, TEXAS

CONTRACT NAS 9-16121
DRL ITEM NO. 4,DRD NO. MA-834T
22 JULY 1981

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FOREWORD

This document contains the detailed final results of the Satellite Services System Analysis Study Part II, performed for NASA Johnson Space Center by Lockheed Missiles & Space Co., Inc. It is submitted, together with the Study Results, Volume II in fulfilment of the requirements (DRL Items MA-834T and MA-745T) of contract NAS 9-16121, which was initiated on 1 August 1980.

This volume includes a summary of the Part I study results previously documented in February 1981.

CONTENTS

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STUDY OBJECTIVES

The Study Objectives are presented in order to orient the reader and to set the stage for the remainder of this presentation.

Satellite Services System Analysis
Study Objectives

PART I

- DEFINITION OF SATELLITE USER MARKET
- ANALYSIS AND DEVELOPMENT OF DESIGN REFERENCE MISSIONS
- DEFINITION OF SATELLITE SERVICES CONCEPT AND SCHEDULE BASED ON DESIGN REFERENCE MISSIONS
- SCOPING OF FULL SATELLITE SERVICE SYSTEM PROGRAM RESOURCES

PART II

- PERFORMANCE OF PRELIMINARY DESIGN OF NEW AND MODIFIED SERVICE EQUIPMENT
- PREPARATION OF PROGRAM AND OPERATIONS PLAN
- DEVELOPMENT OF RESOURCES REQUIREMENTS

STUDY METHODOLOGY

This chart shows an overview of the tasks which made up the Satellite Services System Analysis Study and their progression.

The early mission model was developed through a survey of the potential user market which included NASA, DoD, commercial and international space ventures. Service functions were defined and a group of design reference missions were selected which represented needs for each of the service functions. Servicing concepts were developed through mission analysis and STS timeline constraint analysis.

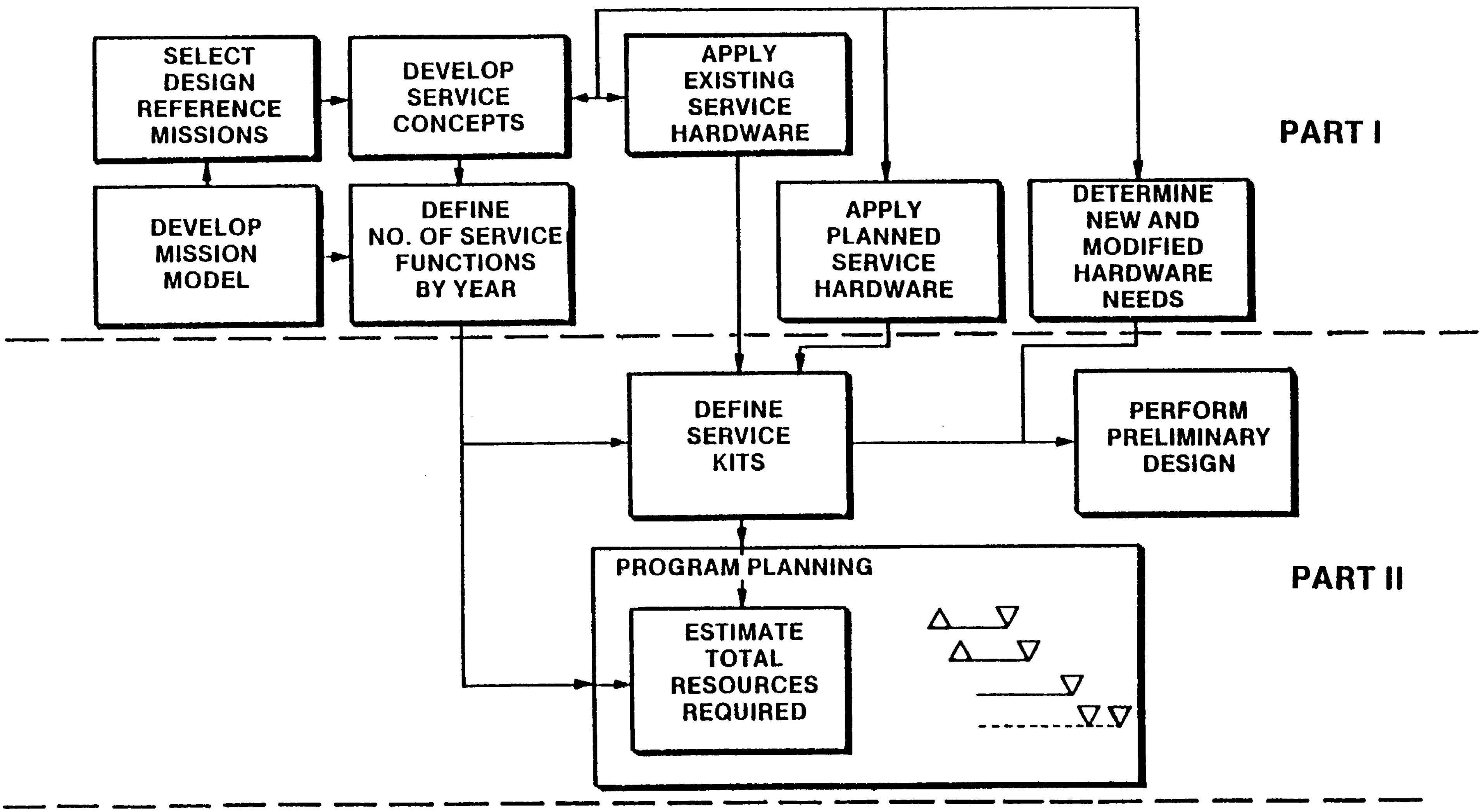
The hardware needs for accomplishing the service functions were identified with emphasis being placed on applying equipment in the current NASA inventory and that in advanced stages of planning.

A more comprehensive service model was developed based on the NASA and DoD mission models segregated by mission class. The number of service events of each class were estimated based on average revisit and service assumptions.

Service Kits were defined as collections of equipment applicable to performing one or more service functions. Preliminary design was carried out on a selected set of hardware needed for early service missions.

The organization and costing of the satellite service systems were addressed in the program planning subtasks.

Study Methodology



PRINCIPAL ACCOMPLISHMENTS

PART I

The accomplishments of Part I of the Satellite Services System Analysis Study have been a logical and traceable progression from the defintion of the satellite user market and the selection of the design reference missions to the definition of a comprehensive set of satellite service functions and the identification of service equipments (existing, modified, new) and their first cut cost estimates.

Principal Accomplishments

Part I

- DEVELOPED SATELLITE USER DATA BASE AND MANAGEMENT COMPUTER PROGRAM
- IDENTIFIED SATELLITE SERVICE FUNCTIONS FOR 1983-93 TIME FRAME
- SELECTED SEVEN DESIGN REFERENCE MISSIONS WHICH ENCOMPASS ALL IDENTIFIED SERVICE FUNCTIONS
- DEFINED REFERENCE SERVICE MISSION FOR TIME LINE AND FIRST CUT COST ESTIMATES
- IDENTIFIED PROBLEMS AND DEVELOPED CONCEPTUAL APPROACHES FOR SATELLITE DEBRIS COLLECTION AND EARTH RETURN
- IDENTIFIED REPRESENTATIVE SATELLITE SERVICE HARDWARE FOR 1983-93 TIME FRAME
- ESTABLISHED NEED AND DEFINED 13 MODIFICATIONS TO NASA EXISTING AND PLANNED EQUIPMENT
- ESTABLISHED NEED AND DEFINED 85 NEW SERVICE EQUIPMENT FOR 1983-93 TIME FRAME
- ESTABLISHED FIRST CUT COST ESTIMATES FOR CANDIDATE SERVICE EQUIPMENT

PRINCIPAL ACCOMPLISHMENTS

PART II

The main accomplishments of Part II have been the generation of preliminary designs of new and modified satellite service equipment required for near-term servicing and the development of programmatic information, including program plan, development schedules and system hardware and user cost estimates.

Principal Accomplishments

PART II

- PERFORMED AND DOCUMENTED PRELIMINARY DESIGN OF REPRESENTATIVE EQUIPMENT NEEDED FOR EARLY IMPLEMENTATION OF SATELLITE SERVICES
- DEVELOPED PROGRAM PLAN AND DEFINED POTENTIAL ORGANIZATIONS INVOLVED IN SATELLITE SERVICES AND THEIR INTERFACES
- DEFINED DEVELOPMENT SCHEDULE IN TWO PHASES
  - EARLY TIME FRAME, LOW COST APPROACH
  - LATE TIME FRAME, EXTENDED CAPABILITIES TO SERVE SPACE SYSTEMS OF THE 1990s
- DEVELOPED SERVICE USER MISSION MODEL THROUGH 1993
- ESTIMATED SYSTEM HARDWARE NEEDS COSTS FOR EARLY TIME FRAME
- PROJECTED TOTAL COSTS TO USERS FOR 1983-1993 PERIOD

S^3 MISSION OBJECTIVE

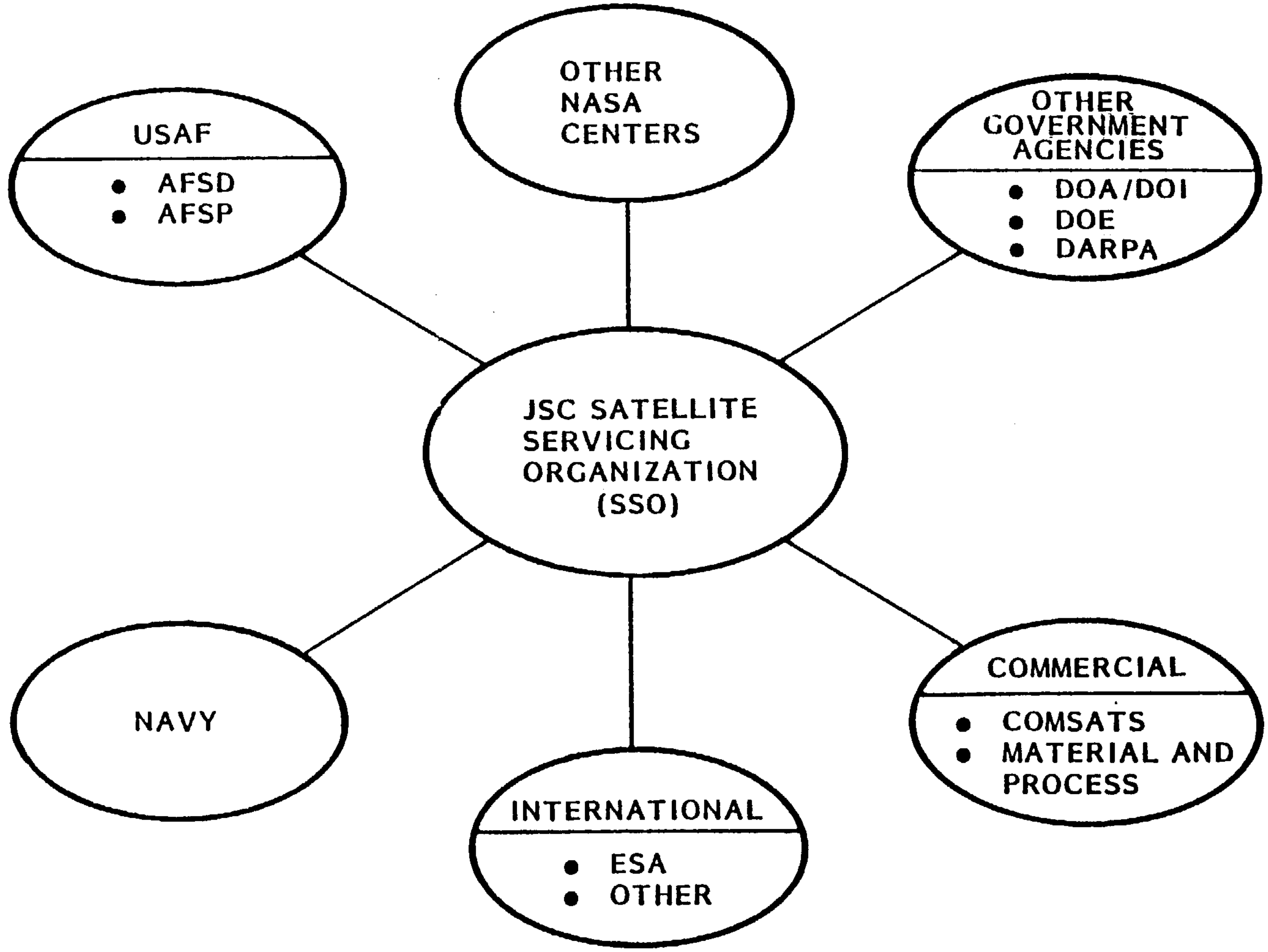
The principal objective of the S^3 implementation is a standardized space servicing system utilized by all agencies with satellite and planetary programs. Lacking this approach, the space operations of the 1980's can become a complicated series of project-unique operations.

A central organization is defined to integrate the needs and operations of the various large user agencies and individual users. S^3 can support a wide variety of users and space vehicles if the proper planning is done. The central-management approach is presented later in a separate chart.

S^3 Mission Objective

PROVIDE A STANDARD SATELLITE SERVICING SYSTEM TO SUPPORT

A WIDE VARIETY OF SPACE MISSIONS



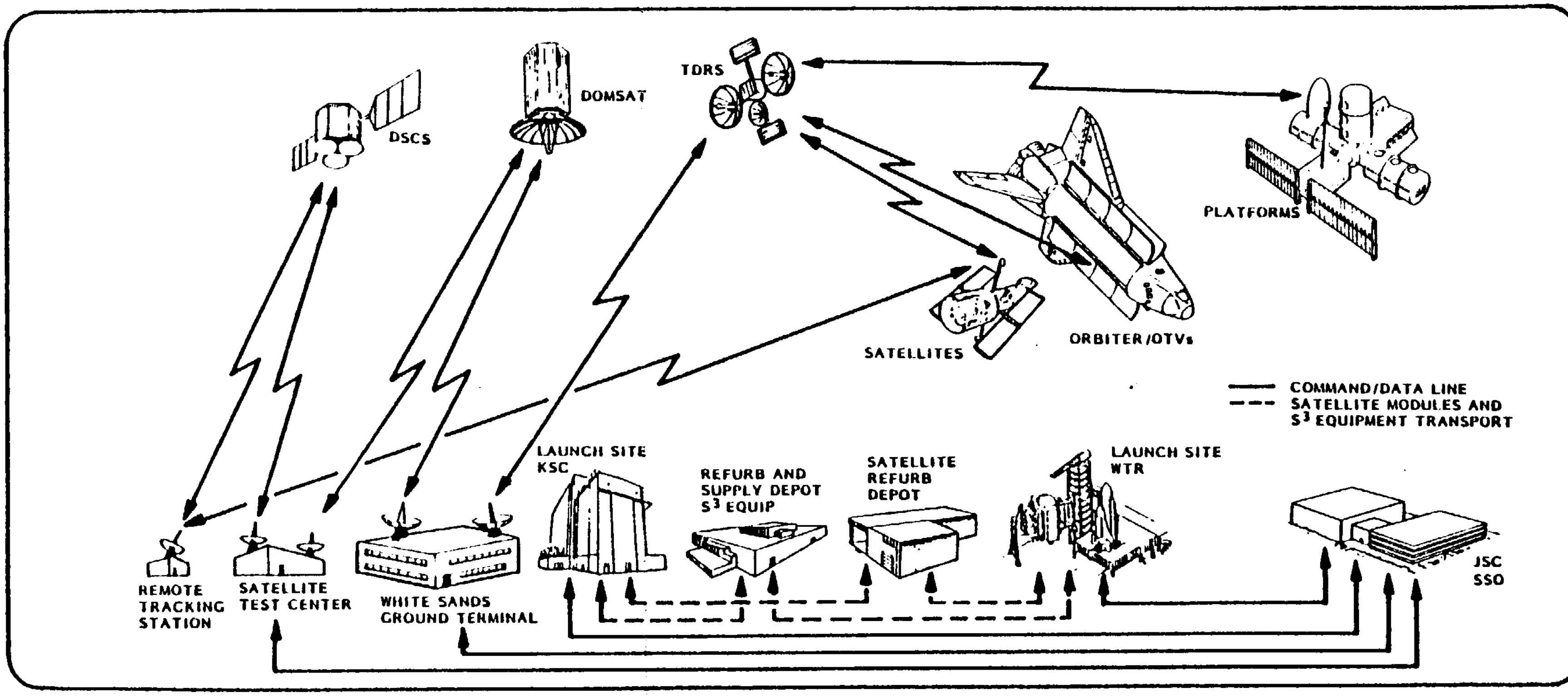
MAJOR ELEMENTS OF THE S^3

The Satellite Service System comprises several major elements as shown. Although the scope of operational S^3 is large, the elements have been integrated into a cost-effective system. The planned development activities support all elements.

Major Elements of the S^3

- S^3 SPACE SUPPORT EQUIPMENT
- LAUNCH SITE EQUIPMENT – SPECIAL
- GSE/STE
- SUPPORT VEHICLES
- GROUND DEPOTS AND FACILITIES
- SPACE DEPOT
- SOFTWARE
- INTEGRATED LOGISTICS SUPPORT

Major Elements of the S^3



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SCOPE OF THE OPERATIONAL S^3

The operational S^3 supports the total earth-orbiting inventory of space vehicles and the checkout/deployment phase of STS launched satellites and planetary mission vehicles.

A multi-agency approach is planned combining the servicing requirements for NASA, DoD, other U. S. Government agencies, and eventually the commercial and international agencies (ESA, Japan, and others).

Scope of the Operational S^3

- SERVICING IS PROVIDED FOR A VARIETY OF SATELLITES, SPACE PLATFORMS (E.G., SOC), OTVs, AND OTHER SPACE SYSTEMS
  - EARLY PHASE (CIRCA 1983) SERVICING INCLUDES:
    - SATELLITE DEPLOYMENT AND RECOVERY
    - ORBITAL UNSCHEDULED EVA OVERRIDE OF APPENDAGES
    - LIMITED CHANGEOUT OF 'MODULES' AND BLACK BOXES
  - LATER PHASES EXTEND SERVICE TO MORE EXTENSIVE CHANGEOUT, RESUPPLY, DEBRIS CAPTURE/RETRIEVAL, REPAIR AND DEORBIT
- ALL STS USERS AND SOME EXPENDABLE LAUNCH VEHICLE USERS ARE POTENTIAL CUSTOMERS FOR S^3: NASA, USAF, DARPA, NAVY, COMMERCIAL, INTERNATIONAL

SPACE SEGMENT S^3 OPERATIONS ELEMENTS

The diagram shows the various elements of the S^3 space segment and their interfaces. The servicing base is shown to be either the Orbiter or the Space Depot (SOC).

S3 Space Segment Operations Elements

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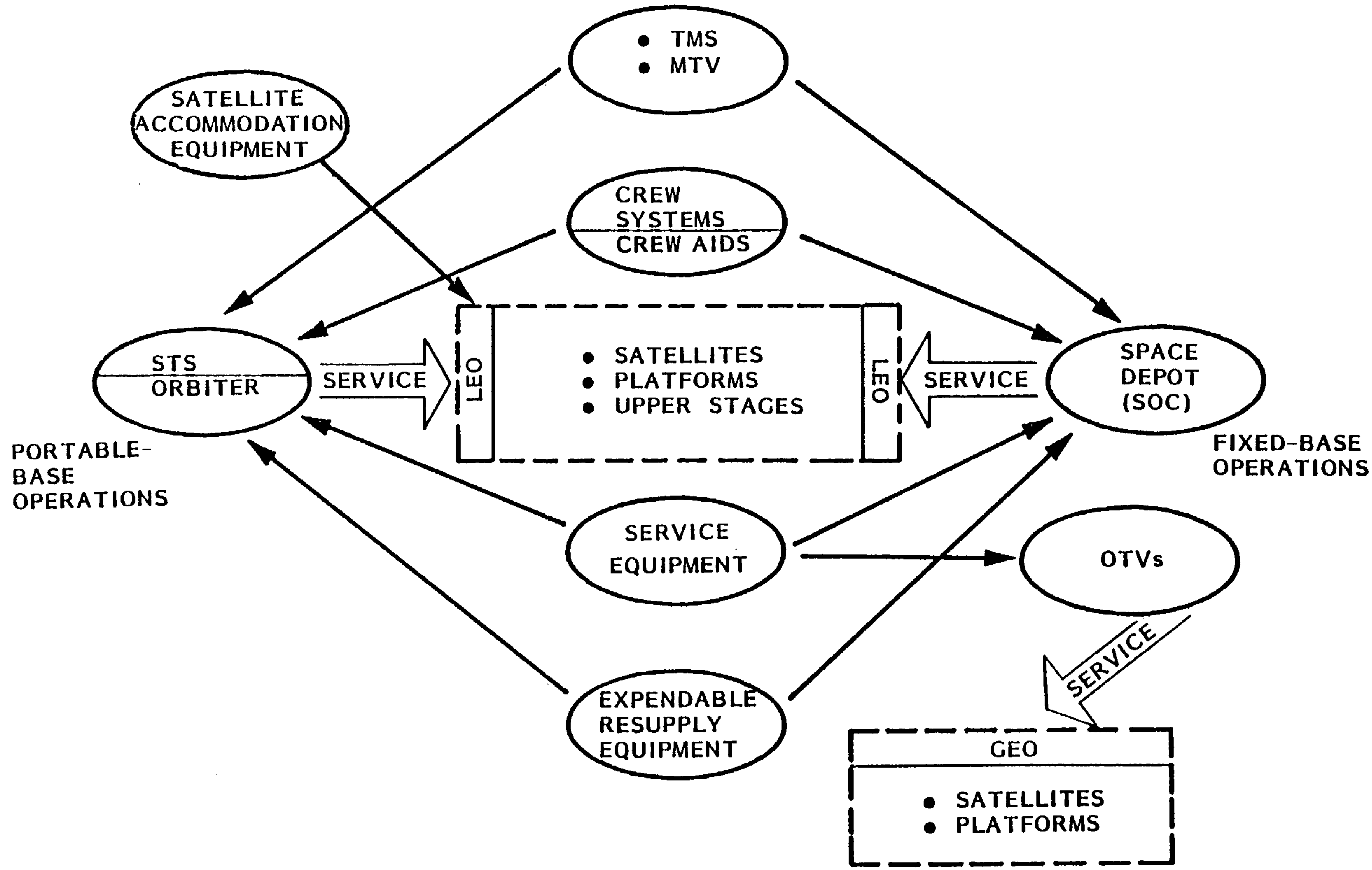
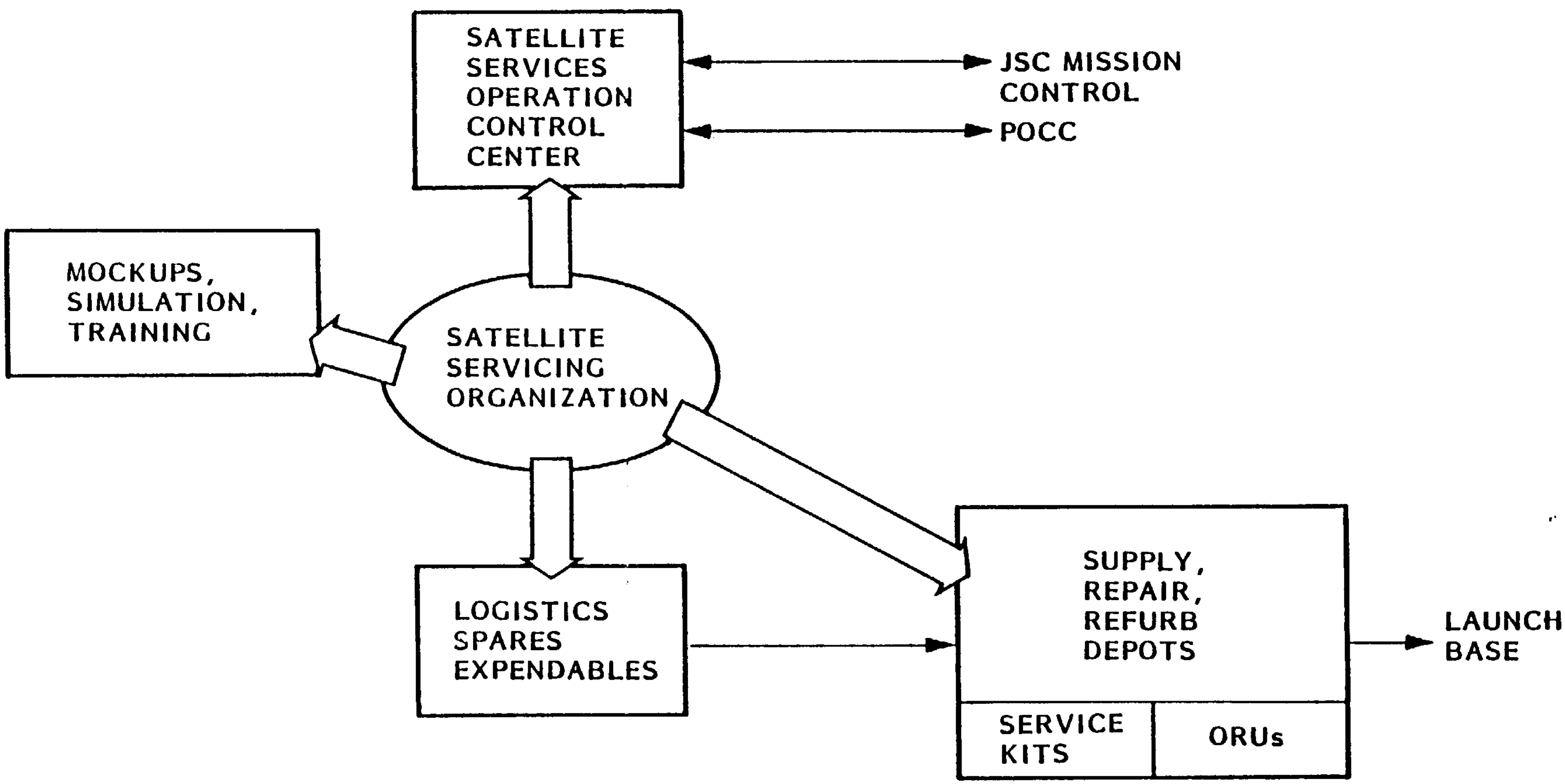


S^3 GROUND SEGMENT OPERATIONS ELEMENTS

The elements of the S^3 Ground Segment are shown in this figure. Examples of the interfaces with the primary operations organizations are indicated.

S^3 Ground Segment Operations Elements



S^3 PLACEMENT IN STANDARD SPACE SYSTEM WBS

The WBS shown in this chart indicates where satellite services is placed in the standardized WBS for Space Systems that has been developed by the Standardization Subgroup of the joint Government/ Industry Space Systems Cost Analysis Group.

S^3 Placement in Standard Space System WBS

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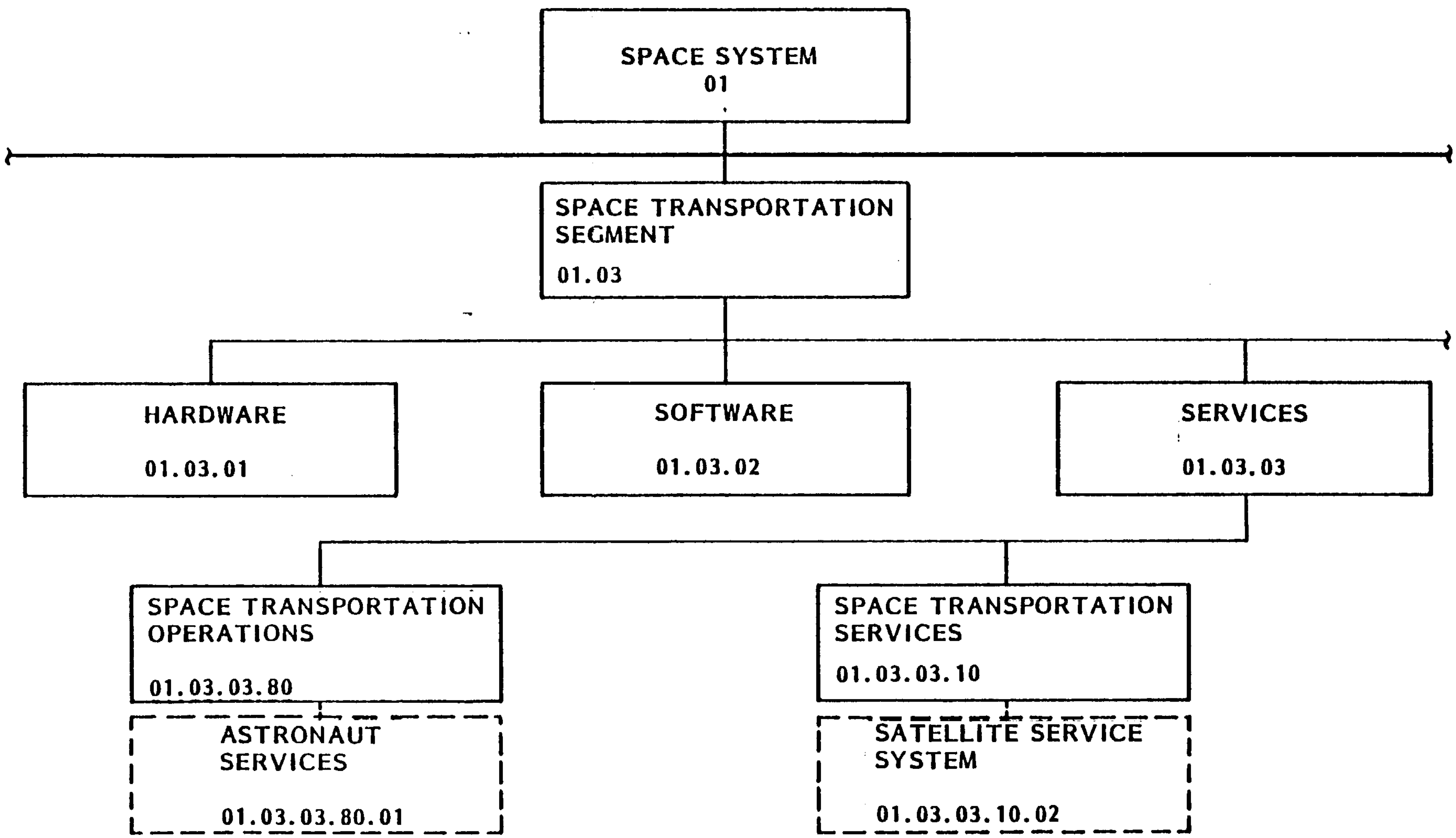


TOP LEVEL S^3 WBS

This chart shows the top-level Satellite Services functions and cost accumulation blocks.

The standardized Work Breakdown Structure (WBS) has been developed by the Standardization Subgroup of the joint Government/industry Space Systems Cost Analysis Group. This WBS features a common 4-level structure that applies to all phases of a space system's life cycle. This framework is designed to be tailored in both the end-item and time-phasing dimensions so as to create specific project work breakdown structures that match the programs being procured. In general, levels 1 through 3 are fixed; levels 4 and below are used to implement this tailoring. The philosophy of WBS tailoring may be summarized as follows:

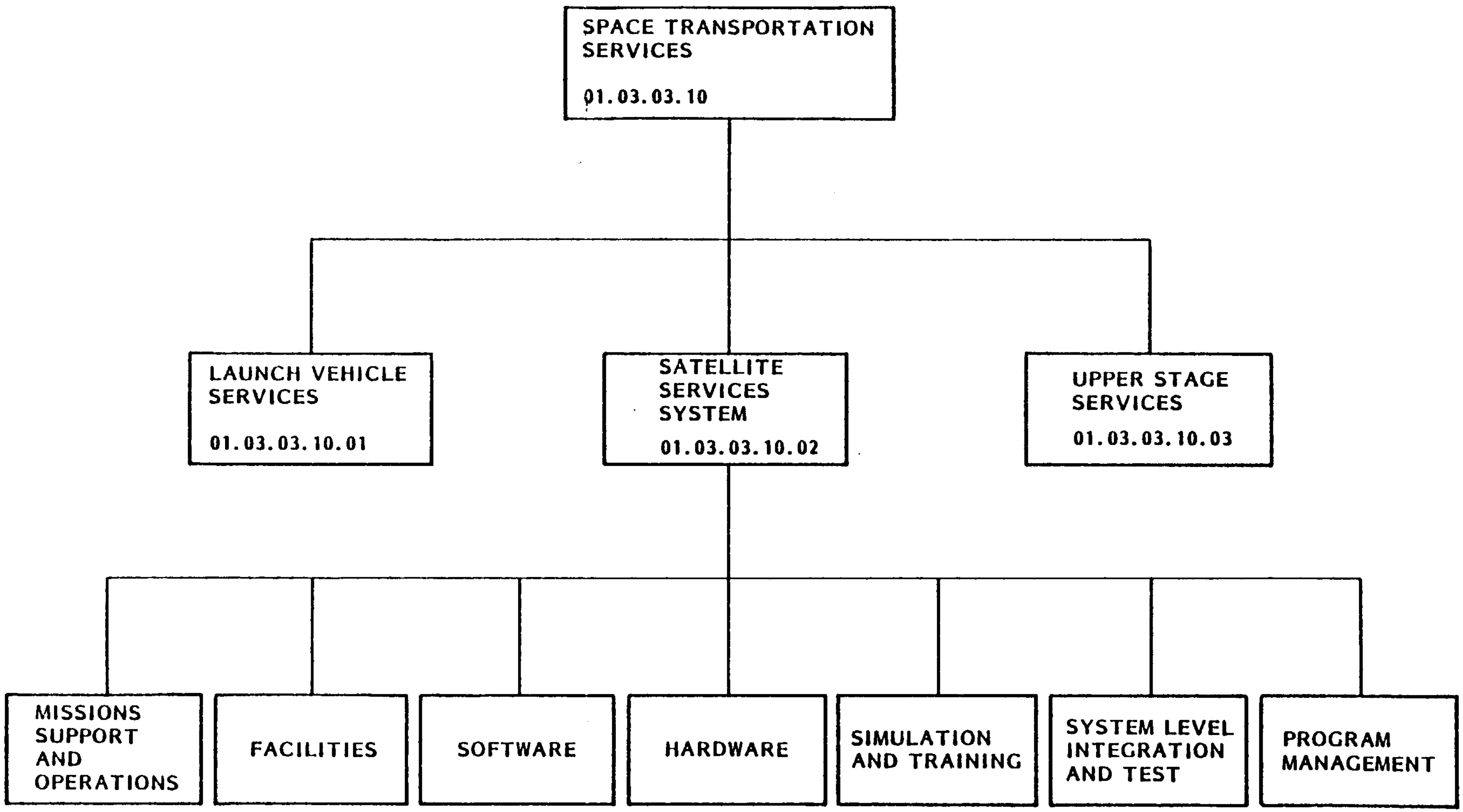
- End-item tailoring is normally accomplished by expanding the WBS blocks for subsystem-level hardware, software and services. However, limited end-item tailoring can also be done at segment level when special circumstances warrant.

- Tailoring in the time-phasing dimension (to distinguish RDT&E, produciton, and O&S phases) is accomplished by deleting WBS blocks that do not apply to the instant phase of a program.

Those end-item codes that end in zero (e.g., 10, 20) flag WBS blocks in which program peculiar tailoring of hardware, software, and services is normally expected. These blocks are to be expanded with appropriate subsystem and lower level end-item breakdowns.

This standard WBS is end-item oriented; that is, it deals with the dimension of program resources that result in a definable and product or service. The other dimensions of program cost; i.e., subdivisions of work and elements of cost, have not been standardized because they tend to be peculiar to each user.

Top Level S^3 WBS



S^3 PROGRAM MANAGEMENT APPROACH

The implementation of an effective Satellite Services System requires effective, well coordinated management. A proposed organization is shown. It includes the central (JSC) Satellite Servicing Organization (SSO) and a directorate for each of the primary functions of the S^3 program.

In addition, working groups and integrating contractors are shown in staff positions to coordinate and maintain interfaces with critical user agencies and support elements.

S^3 Program Management Approach

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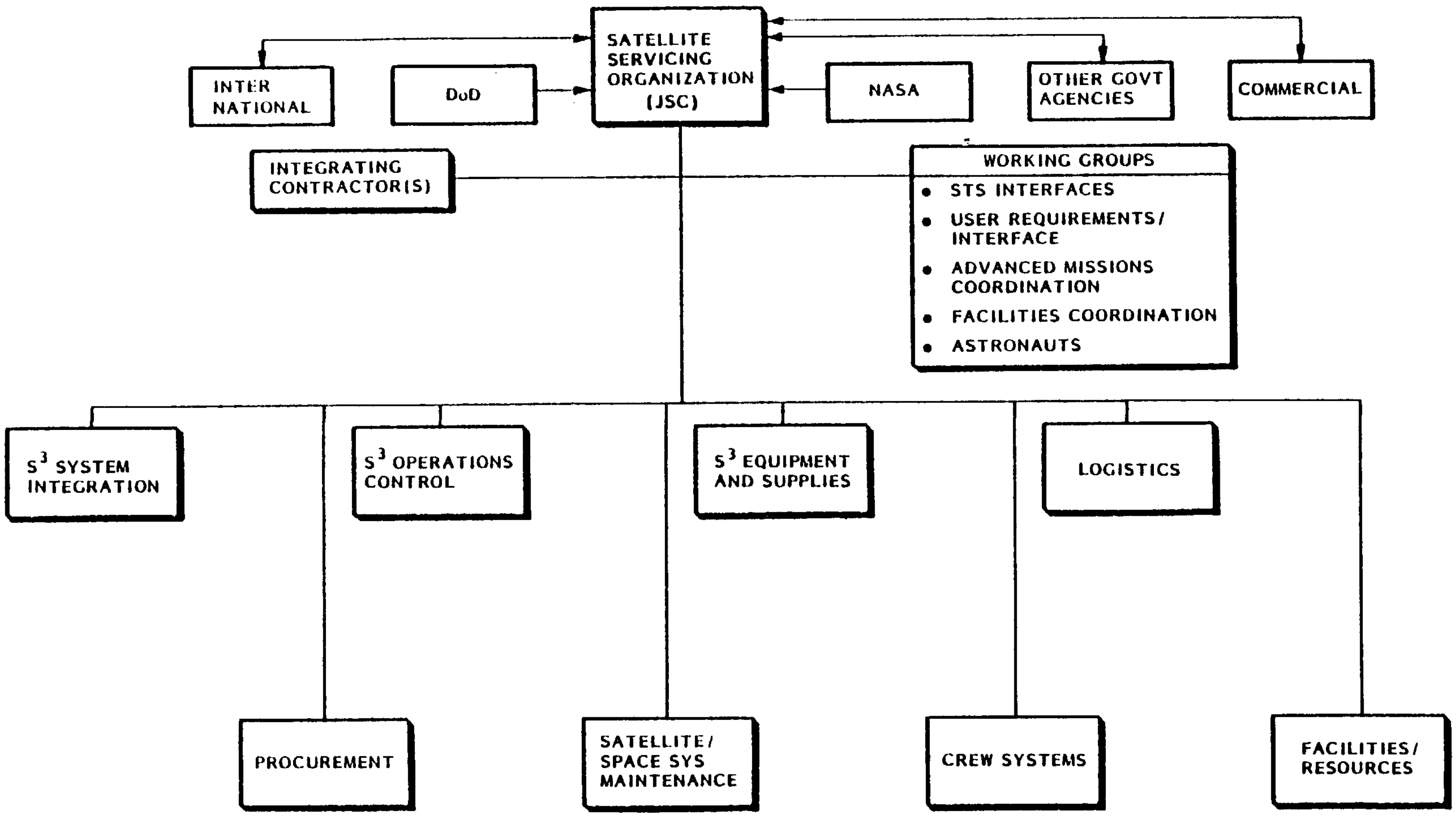

S^3 OPERATIONS PLANS

Two types of Operations Plans are identified and separated in time. The generic mission plans can be generated at the time a clear definition of responsibilities is achieved.

The specific mission plans are generated after manifesting is firm and far enough in advance of the flight date to permit accomplishment of the defined simulations and training. It must also be in time to support facilities scheduling and launch base operations planning.

The Satellite Servicing Orgnaization is responsible for the preparation of these plans and the coordination with all affected organizations and functions. Approvals are anticipated to be required by at least the Mission Planning and Analysis Division and the Flight Operations Panels. Coordination sign-off's are probably required by other associated organizations.

S^3 Operations Plans

GENERIC MISSION PLANS – CAN BE GENERATED EARLY

- DEPLOY
- SORTIE
- REPAIR
- CHANGEOUT
- RECONFIGURE
- RESUPPLY
- EARTH RETURN
- DEORBIT

SPECIFIC MISSION PLANS – PREFLIGHT GENERATED/FORMALIZED/ APPROVED

- SOLAR MAXIMUM
- SPACE TELESCOPE
- LDEF
- - - - - -
- - - - - -
- - - - - -

SYSTEM COST OVERVIEW

Seven Generic Missions were defined in the course of the SSSA Study Part II. These missions are generalizations of the real planned STS missions that are candidates for in-orbit service. To arrive at a total system cost, averages were used in terms of equipment carried, time spent in orbit, the number of EVA's, etc. The total mission model was based on assumptions on the frequency of need of revisit, and the numbers of spacecraft designed for in-orbit service.

The compliment of service equipment required to support the total mission model was defined and the cost of procuring that equipment estimated using a parametric approach (The RCA "RRICE" Model).

The unit service event cost to the user was estimated by prorating the cost of the service equipment, adding the STS costs (shared cargo, time in orbit, payload special lists, etc.). The total cost to the users was then derived from the unit service event costs multiplied by the number of such events predicted by the mission model in the time frame of 1983-1993.

The results are shown in this chart. The first pie figure indicates the proration of the service system hardware costs. This is the funding requirements for NASA to establish the needed equipment inventory. The second shows the distribution of the service mission types in the whole mission model. The third shows the system user cost breakdown to the generic missions.

System Cost Overview

1983 - 1993

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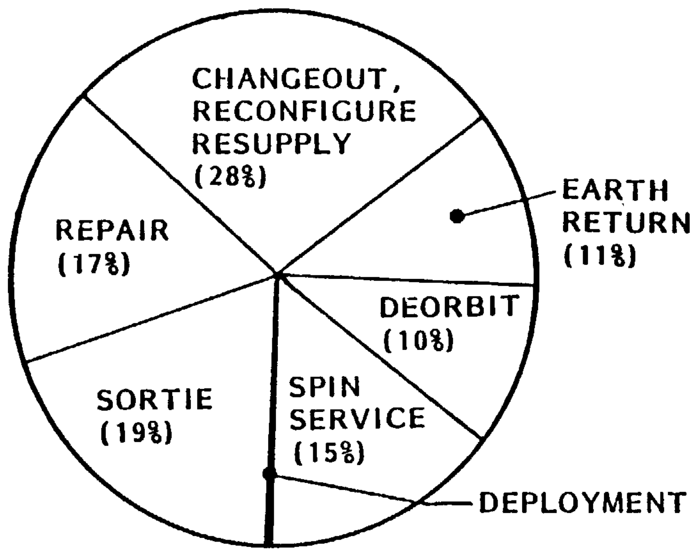
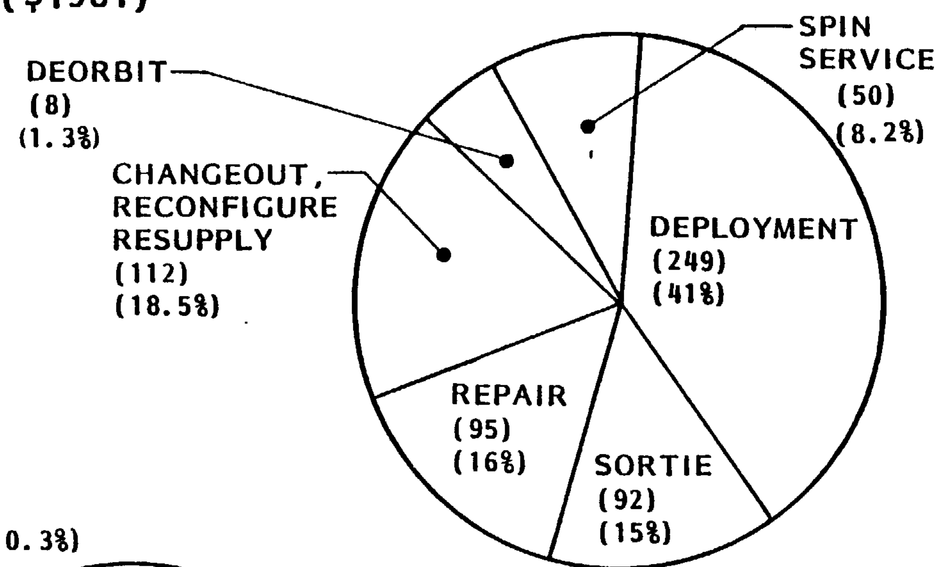
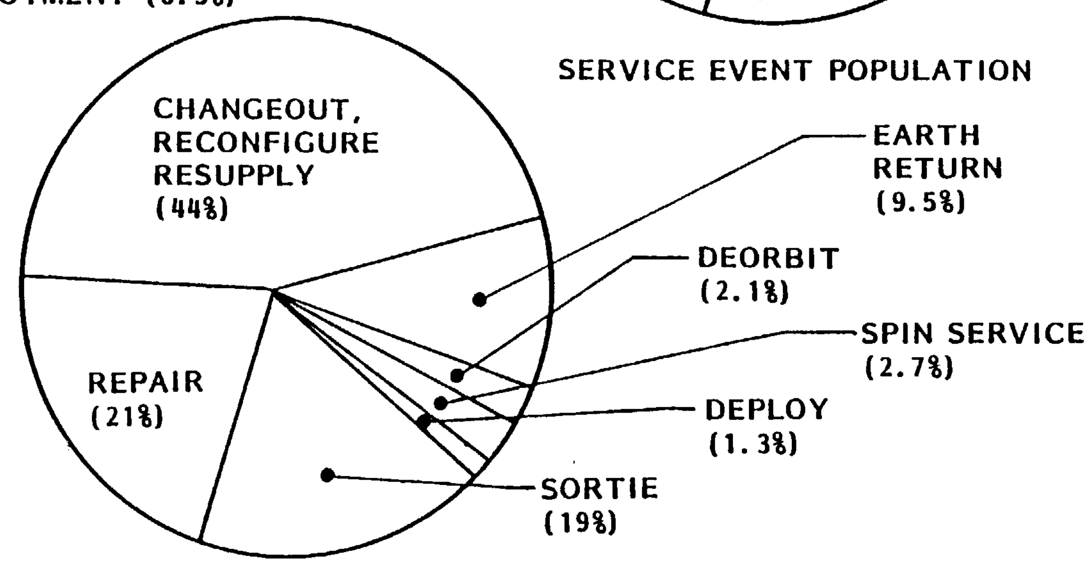
($1981)



PRORATED HARDWARE COST
($205M THROUGH 1987)



SERVICE EVENT POPULATION



TOTAL USER COST BREAKDOWN ($2.12B)

SYSTEM LEVEL COST ELEMENTS

The elements that were included in and excluded from the system cost estimates are indicated in this chart. The RCA "PRICE" model includes the DDT&E, program management, test, integration etc., for each of the 66 identified equipments that make up the service kits. Other costs are derived from the STS Cost Reimbursement guide and experience factors for similar programs.

The cost factors that were found to be intractable at this time are listed on the right. The assumption was made that the STS Orbiter could rendezvous with those satellites which are free flyers either because they utilize one of the STS standard orbits or are capable of returning from their operational orbit to the orbiter by antonomous means or through the action of another stáge (e.g., TMS).

System Level Cost Elements

INCLUDED IN COST ESTIMATE
SERVICE KIT EQUIPMENT
DDT&E
PRODUCTION
AGE/STE
SUPPORT SOFTWARE
REFURBISHMENT
SPACE TRANSPORTATION
SHARED LAUNCH CHARGE
INSTALL/REMOVE TIME
ON-ORBIT SUPPORT TIME
EVA
PAYLOAD SPECIALIST
SIMULATION AND TRAINING
PROGRAM MANAGEMENT
SYSTEM ENGINEERING AND INTEGRATION
FACILITIES

INSUFFICIENT DEFINITION FOR INCLUSION
OMS KITS
COMMUNICATIONS FOR FLIGHT OPERATIONS
DELIVERABLE SOFTWARE
MISSION DATA PROCESSING AND REPORTING
GROUND SUPPORT OF FLIGHT OPERATIONS

S^3 EQUIPMENT COST

This chart represents the funding required to procure the hardware to support the mission model. The year by year and cumulative funding is indicated.

For the extended capability S^3 more complex equipment is required e.g., OTV, TMS, Platform docking equipment, etc. The expenditures for these were not estimated but are also shown in dashed lines on this chart. The start date for development of the extended capability equipment depends on the projected need for these capabilities. The dates shown here are the earliest likely.

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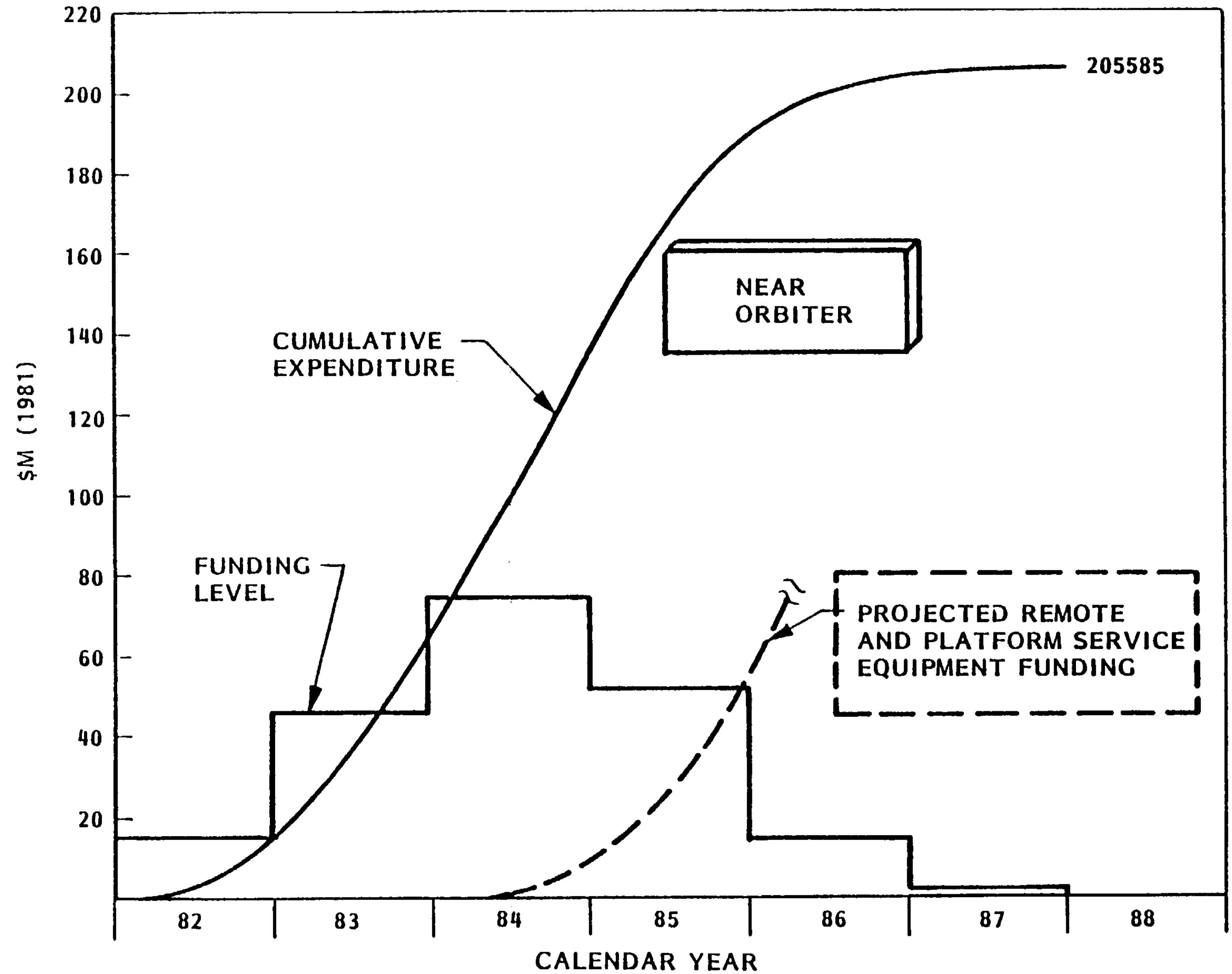
S^3 Equipment Cost



UNIT SERVICE EVENT COST BREAKDOWN

It is evident from the "Recurring Cost" estimate that the STS Transportation cost is the predominant factor in the the user unit service cost. This chart shows the percentage breakdown for the support (Changeout, Reconfigure, Resupply) class of service mission. The STS transportation cost has been broken out from the other recurring charges.

The costs to the user which are directly controllable by the Satellite Services Organization are a small fraction of the total.

Unit Service Event Cost Breakdown

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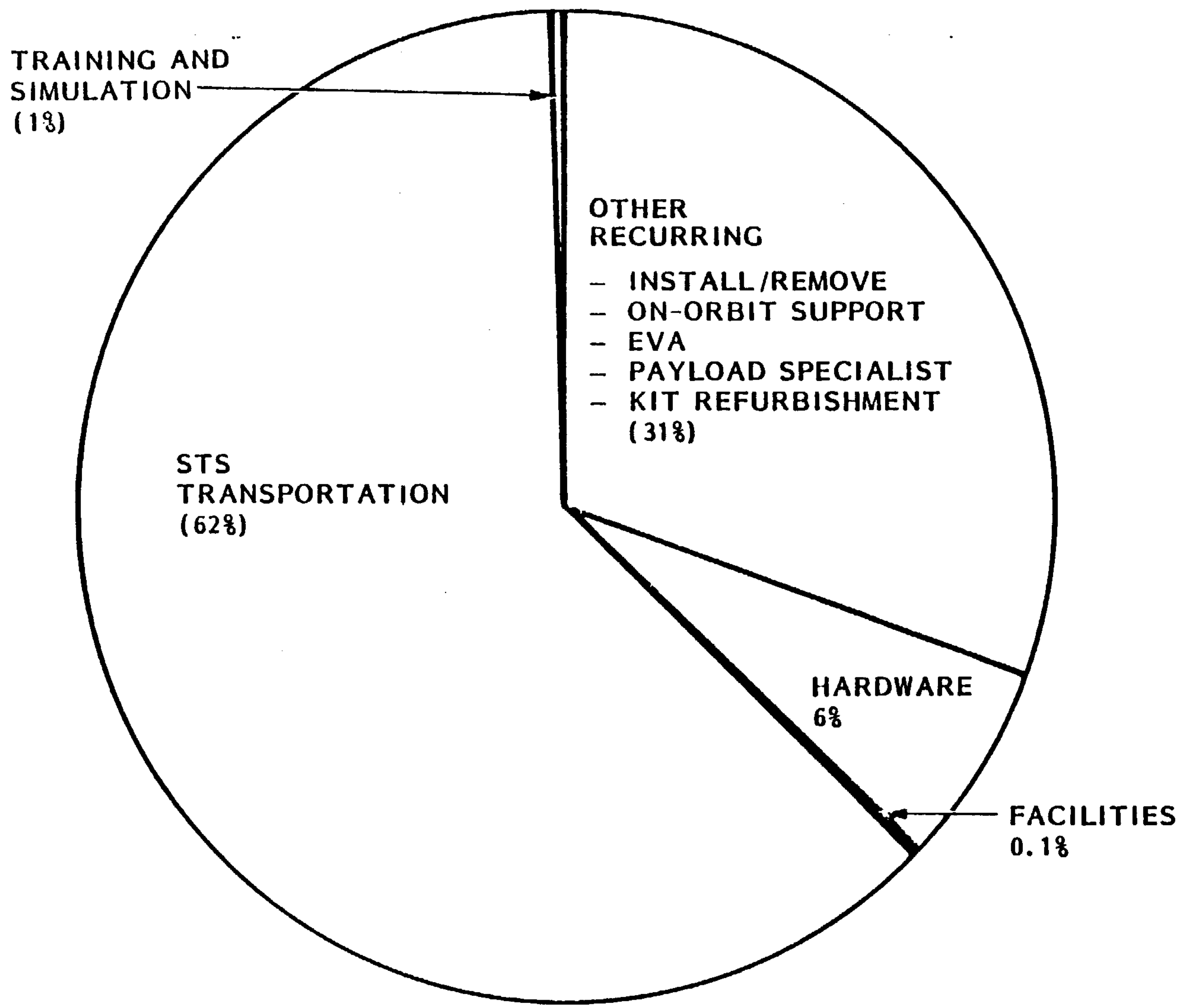
PRORATED SYSTEM COST



CHANGEOUT, RECONFIGURE, RESUPPLY

TYPICAL PRELIMINARY DESIGN HARDWARE

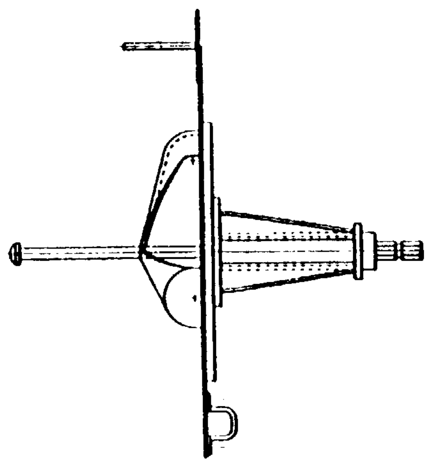
Five elements of the ten preliminary equipment designs are presented. The portable grapple fixture is designed for use in retrieval of satellite or space debris which is not fitted with a grapple fixture. The standoff is designed with a hexagonal male stud which mates with the female receptacle and locks in place with a PIP Pin. For the cases where the satellite being retrieved was not fitted with the female receptacle, several alternatives were configured for attaching the receptacle during EVA.

The portable foot restraint is an extensive modification of the existing NASA standard foot restraint. The portability is achieved by providing a hexagonal male stud which mates with the same receptacle as used for the grapple fixture. In this way the attachment capability of the receptacle is applicable to both uses. Articulation is provided to allow the astronaut additional positioning flexibility. The 3 axis articulation is accomplished by foot controls which are readily accessible by the crew person.

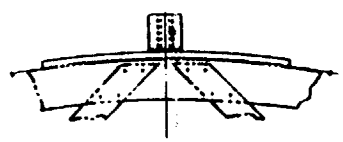
The deployment and maintenance platform is designed to perform the functions of aiding the deployment of the spacecraft or stowing it for earth return. In this respect it performs the functions sometimes referred to as the "Payload Insertion and Deployment Aid". As added functions, it provides a berthing platform which holds a recovered satellite. Its pivoting and rotation capability support maintenance (service) operations from the orbiter bay. These latter functions are sometimes referred to as "Holding and Positioning Aid".

The cargo bay rack serves several functions. It is used as an intermediate stowage or handling area when a number of tools must be brought from the stowage container to the satellite work site. Secondly, it provides an open, flat surface used as a work bench for planned and unscheduled service operations. Finally, it serves as a cargo tie-down platform for use in recovery/earth return operations of satellites and space debris which have no provisions for normal cargo bay stowage. It is designed to fit over the OMS Kits and make use of cargo bay volume otherwise not easily utilized.

Typical Preliminary Design Hardware



PORTABLE GRAPPLE FIXTURE



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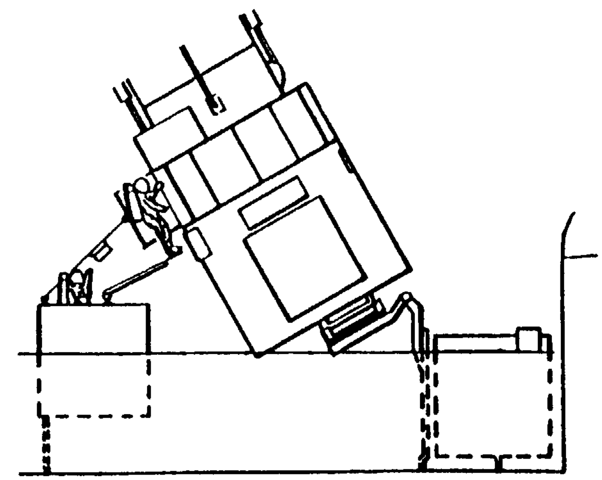
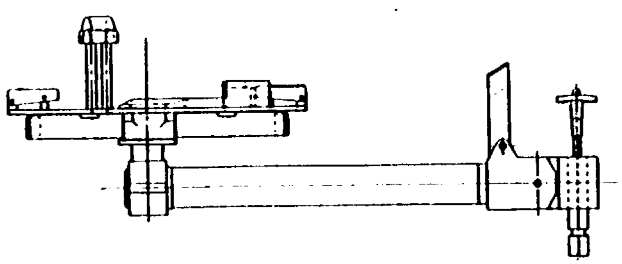
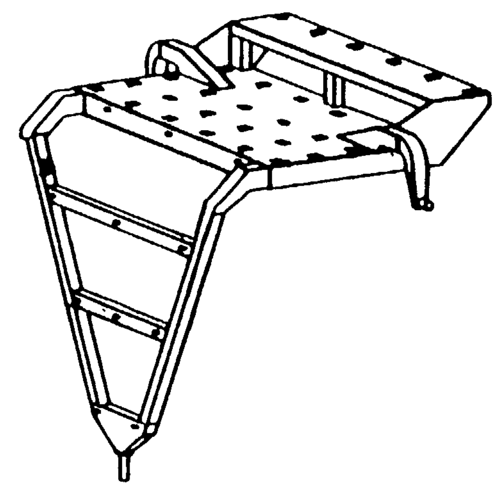


DEPLOYMENT AND MAINTENANCE PLATFORM



PORTABLE FOOT RESTRAINT



CARGO BAY RACK

S^3 EQUIPMENT DEVELOPMENT SUMMARY SCHEDULE

This summary schedule for the S^3 equipment Development and Production phase is divided into two parts showing separately the Near-Orbiter or early S^3 equipment schedule and the longer term HEO/GEO service hardware development schedule.

Compressing the schedule is feasible if a high-priority is assigned to the S^3 program and prototype development and flight test approach is adopted. The flight dates for full complements of S^3 equipment under normal development scheduling appear to lag the need dates for several of the planned NASA missions.

The implementation of facility designs also is critical. To have the facility modification completed when needed for S^3 operations design should start no later than mid-1982.

Summary S^3 Equipment Development Schedule

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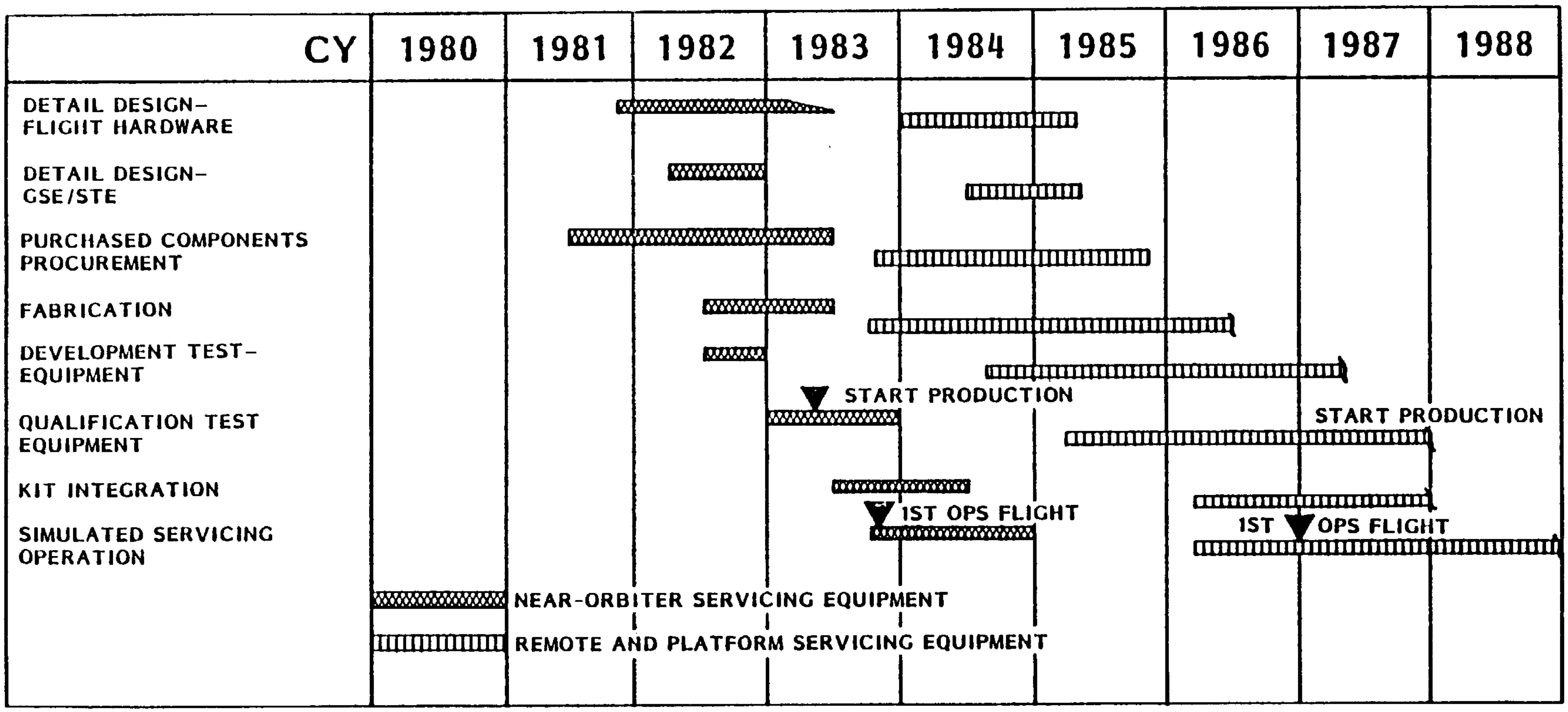

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S^3 EVOLUTION

An evolutionary approach is proposed for the development of the Satellite Services System, in order to keep early year funding relatively low and to take advantage of the existing and soon to be available service equipment.

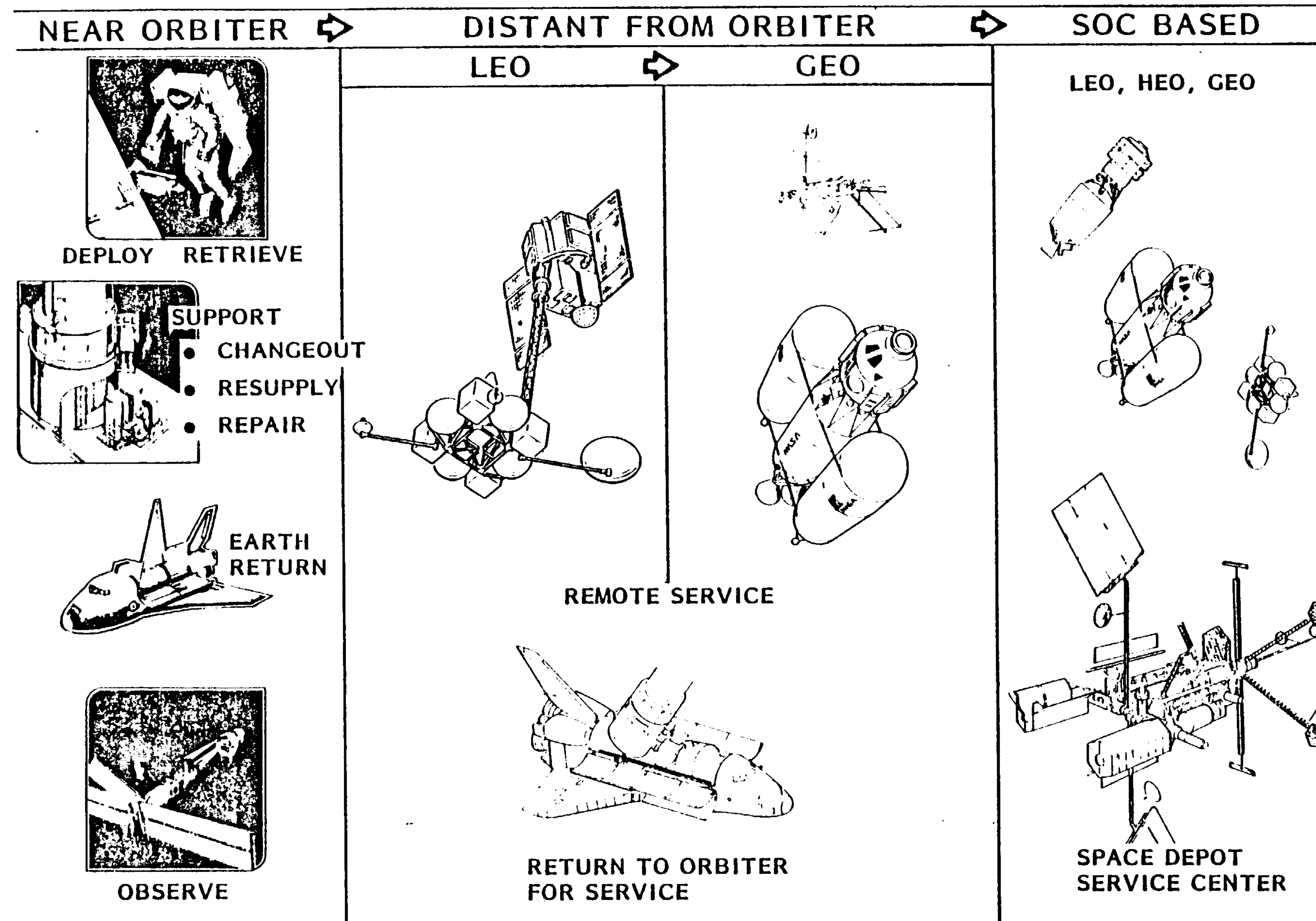
Three major evolutionary steps are envisioned:

INITIAL: Near-Orbiter servicing, involving satellites and services in LEO, directly accessible by the STS

EXPANDED: Distant from Orbiter servicing, first in LEO not directly accessible by the STS and subsequently in GEO.

SPACE BASED: With the availability of the Space Operations Center in 1989-1990, space based servicing will become possible for co-orbiting satellites, and satellites in LEO, HEO and GEO.

S^3 Evolution



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Principal Conclusions

- THE VERSATILITY OF MAN-IN-SPACE CAN BEST BE AUGMENTED BY PROVIDING THE ASTRONAUTS WITH SIMPLE TOOLS AND AIDS THAT FACILITATE A WIDE VARIETY OF SERVICE FUNCTIONS TO BE PERFORMED BY EVA
  - THIS APPROACH LENDS ITSELF TO EARLY IMPLEMENTATION AT MINIMUM COST
  - MUCH OF THE EQUIPMENT NEEDED FOR IMMEDIATE AND NEAR-TERM SERVICING EXISTS TODAY

Principal Conclusions (Contd)

- MODULAR SERVICE EQUIPMENT DESIGNED FOR MULTI-MISSION APPLICATION CAN ACCOMPLISH ALL IDENTIFIED NEAR-ORBITER SERVICE FUNCTIONS
  - THIS BASELINE EQUIPMENT COMPLEMENT FORMS THE BASIS FOR EXTENSION OF SERVICING TO HEO/GEO AND SOC BASED SERVICING
- SERVICE EXTENSION TO HEO/GEO REQUIRES OTV DEVELOPMENT
- EARLY IMPLEMENTATION CAN BE ACCOMPLISHED AT MODERATE FUNDING LEVELS FOR SERVICE EQUIPMENT

1982	$15M
1983	$47M
1984	$74M

TOTAL THROUGH 1967 = $205M

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Recommendations

- THE IMMEDIATE PRIORITY GOALS PERCEIVED ARE TO:
  - DEFINE SCOPE OF "SATELLITE SERVICES"
  - DEFINE OVERALL SYSTEM ELEMENTS AND INTERFACES
  - ESTABLISH GENERALIZED USER REQUIREMENTS
  - OBTAIN USER AGENCY SUPPORT OF CENTRALIZED SATELLITE SERVICES ORGANIZATION
  - ESTABLISH "DESIGN-FOR-SERVICE" CONSCIOUSNESS IN SPACE COMMUNITY

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- TASK 1: MISSION REQUIREMENTS AND ECONOMIC ANALYSIS
  - CONDUCT AN ANALYSIS TO ESTABLISH THE BENEFITS TO THE USERS OF ON-ORBIT SERVICING

- TASK 2: CARGO CONTAINMENT SYSTEM DEFINITION
  - PERFORM A PRELIMINARY DESIGN AND PRODUCE A TOP LEVEL SPECIFICATION FOR THE CONTAINMENT OF SPACE OBJECTS THAT WERE NOT DESIGNED FOR EARTH RETURN IN THE ORBITER

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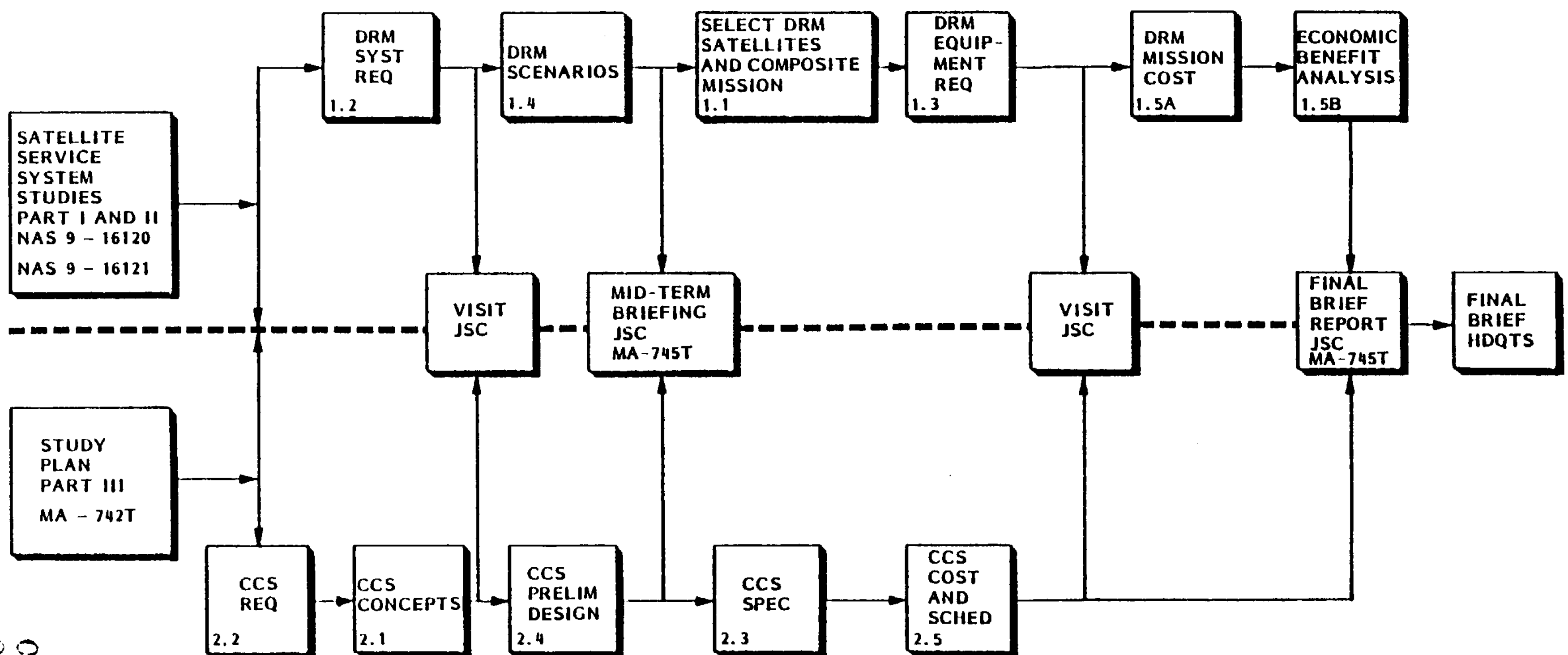
Part III Study Logic Flow

TASK I MISSION REQUIREMENTS AND ECONOMIC ANALYSIS



TASK II CARGO CONTAINMENT SYSTEM DEFINITION

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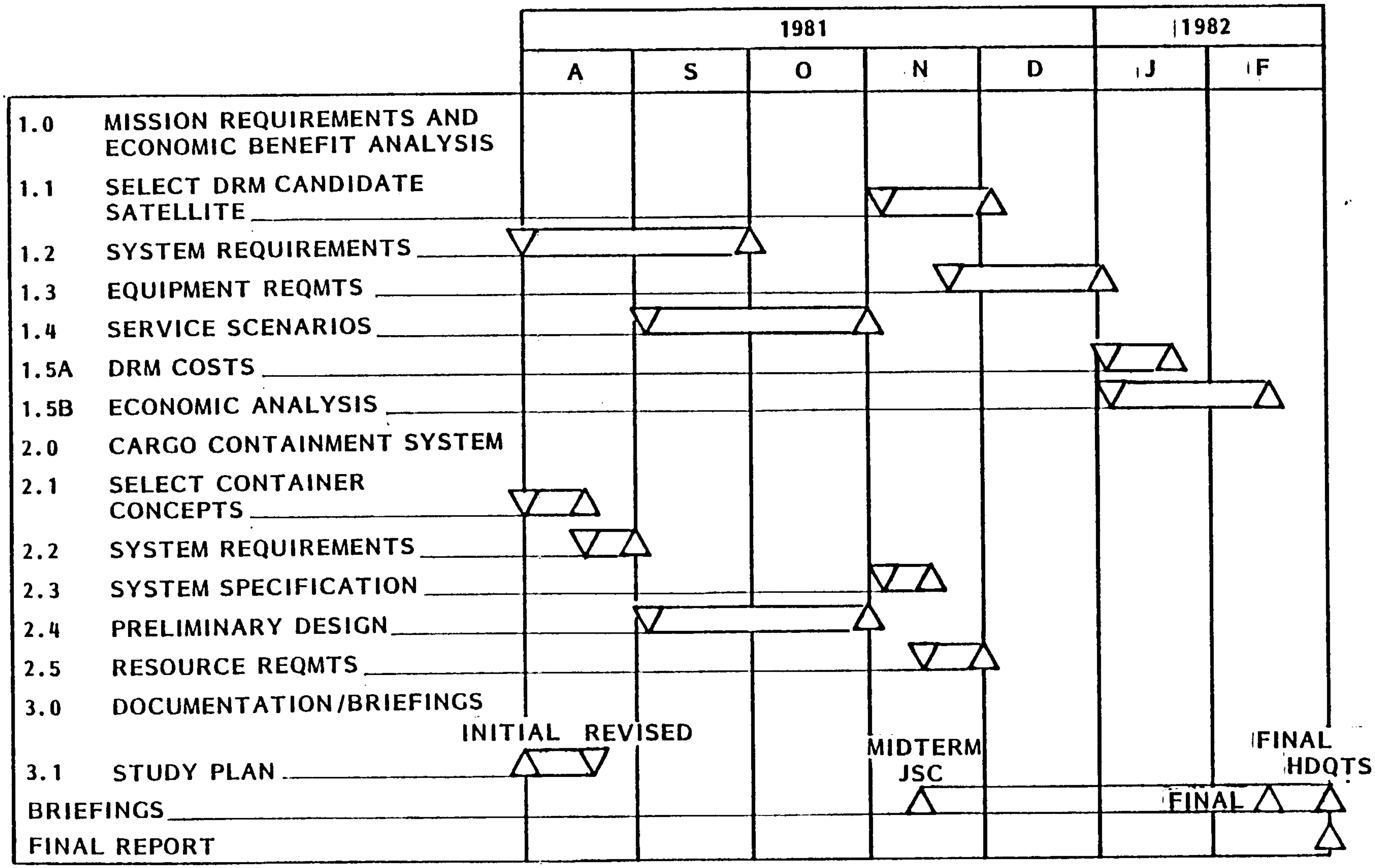
STUDY SCHEDULE



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